Minority-carrier lifetime of BaSi$_2$ formed on various multicrystalline Si substrates

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Introduction We have been focusing on BaSi$_2$ as a new candidate material for thin-film solar cell because not only a large absorption coefficient ($\alpha=3\times10^4$ cm$^{-1}$@1.5 eV) but also a large minority-carrier lifetime (~10 μs) can be utilized in BaSi$_2$ epitaxial layers formed on a Si (111) substrate$^{[1,2]}$. However, to realize the mass production of BaSi$_2$, inexpensive substrates such as multicrystalline Si (mc-Si) and glass are needed for BaSi$_2$ fabrication. Recently, we have formed BaSi$_2$ on mc-Si substrates. It is thus of significant importance to investigate the properties of non-epitaxial BaSi$_2$ films formed on those substrates. In this study, we fabricated BaSi$_2$ films on various mc-Si substrates with different grain size and grain orientations, and measured their minority-carrier properties by microwave-detected photoconductivity decay (μ-PCD) method.

Experiment We adopted two kinds of mc-Si substrates. The grains of substrate A are small and randomly oriented. On the other hand, substrate B has (111) highly oriented grains and larger grain size than substrate A. Over 500 nm undoped n-BaSi$_2$ layers capped with 8 nm α-Si were grown on those substrates by MBE method. The crystal orientation of BaSi$_2$ was investigated by X-ray diffraction (XRD). The minority-carrier lifetime was measured by μ-PCD method. Electron-hole pairs were generated by a 5 ns laser pulse with a wavelength of 349 nm and photoconductivity decay was measured by the reflectivity of microwave with the frequency of 26 GHz. The photon flux density was $1.1\times10^{13}$ cm$^{-2}$ s$^{-1}$.

Results & Discussions The effective lifetime ($\tau_{\text{eff}}$) vs reflected microwave intensity ($I$) curves can be divided into three parts. According to our previous research, $\tau_{\text{eff}}$ of SRH recombination part can represent the lifetime of BaSi$_2$ layers$^{[3]}$. Figure 1 shows the $\tau_{\text{eff}}$ of BaSi$_2$ grown on substrate A. We can see that sample 4 grown at 580°C had larger $\tau_{\text{eff}}$ than those of samples grown at holder temperatures of 550 & 600°C, meaning that 580°C might be an appropriate temperature for BaSi$_2$ on substrate A. On the other hand, Fig. 2 shows the results of BaSi$_2$ grown on substrate B. In this case, sample 4 grown at 580°C shows the roughest surface, which may attribute to the smallest $\tau_{\text{eff}}$ of 0.6 μs, possibly because that 580°C was not sufficiently high for substrate B. Samples 5&6 were grown at 650°C at the same time. Sample 6 had higher $\tau_{\text{eff}}$ than sample 5, which is probably due to the fact that the existence of epitaxial BaSi$_2$ part can attribute to higher $\tau_{\text{eff}}$ in sample 6. Comparing with $\tau_{\text{eff}}$ of epitaxial BaSi$_2$ grown on Si (111) substrates, those of BaSi$_2$ grown on mc-Si substrates show smaller $\tau_{\text{eff}}$ around 1 μs. This can be attributed to the crystal quality and surface roughness of BaSi$_2$ grown on mc-Si substrates.

References


![Fig 1 $\tau_{\text{eff}}$ as a function of the reflected microwave intensity ($I$) for samples 1-3 grown on substrate A. The photo density is $1.1\times10^{13}$ cm$^{-2}$](image1.png)

![Fig 2 $\tau_{\text{eff}}$ as a function of the reflected microwave intensity ($I$) for samples 4-6 grown on substrate B. The photo density is $1.1\times10^{13}$ cm$^{-2}$](image2.png)